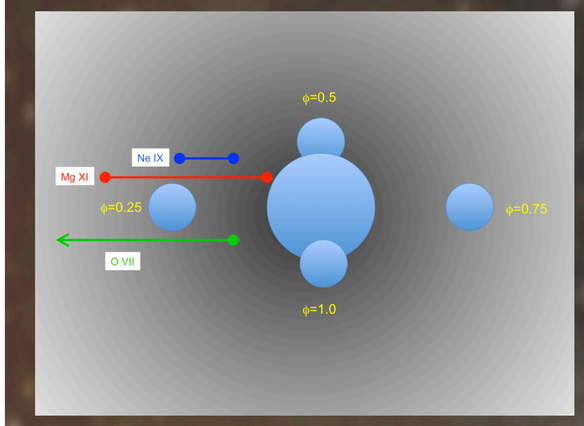
The Chandra Delta Ori Large Project: Occultation Measurements Of The Shocked Gas In The Nearest Eclipsing O-Star Binary

Michael F. Corcoran (USRA & NASA/GSFC), Joy Nichols (SAO), Yael Naze & Gregor Rauw (U. Liege), Andrew Pollock (ESA), Anthony Moffat & Noel Richardson (U. Montreal), Nancy Evans (SAO), Kenji Hamaguchi (UMBC & NASA/GSFC), Lida Oskinova & W.-R. Hamann (Potsdam), Ted Gull (NASA/GSFC), Rico Ignace & Tabetha Hole (East Tennessee State), Rosina Iping (UMCP), Nolan Walborn (STScI), Jennifer Hoffman & Jamie Lomax (U. Denver), Wayne Waldron (Eureka Scientific), Stan Owocki (U. Delaware), Jesus Maiz-Apellaniz (IA Andalucia-CSIC), Maurice Leutenegger (UMBC & NASA/GSFC), Tabetha Hole (Weber), Ken Gayley (U. Iowa), Chris Russell (JSPS/Hokkai-Gakuen University) and the MOST team



Schematic of the orbit of the secondary star around the primary in Delta Ori. The bars show the estimate of the formation regions of Ne IX, Mg XI and O VII from Miller et al. (2002 ApJ, 577, 951).

Introduction

Delta Ori is the nearest massive, single-lined eclipsing binary (O9.5 II + B0.5III). As such it serves as a fundamental calibrator of the mass-radius-luminosity relation in the upper HR diagram. It is also the only eclipsing O-type binary system which is bright enough to be observable with the CHANDRA gratings in a reasonable exposure. Studies of resolved X-ray line complexes provide tracers of wind mass loss rate and clumpiness; occultation by the X-ray dark companion of the line emitting region can provide direct spatial information on the location of the X-ray emitting gas produced by shocks embedded in the wind of the primary star. We obtained phase-resolved spectra with Chandra in order to determine the level of phase-dependent vs. secular variability in the shocked wind. Along with the Chandra observations we obtained simultaneous photometry from space with the Canadian MOST satellite to help understand the relation between X-ray and photospheric variability.

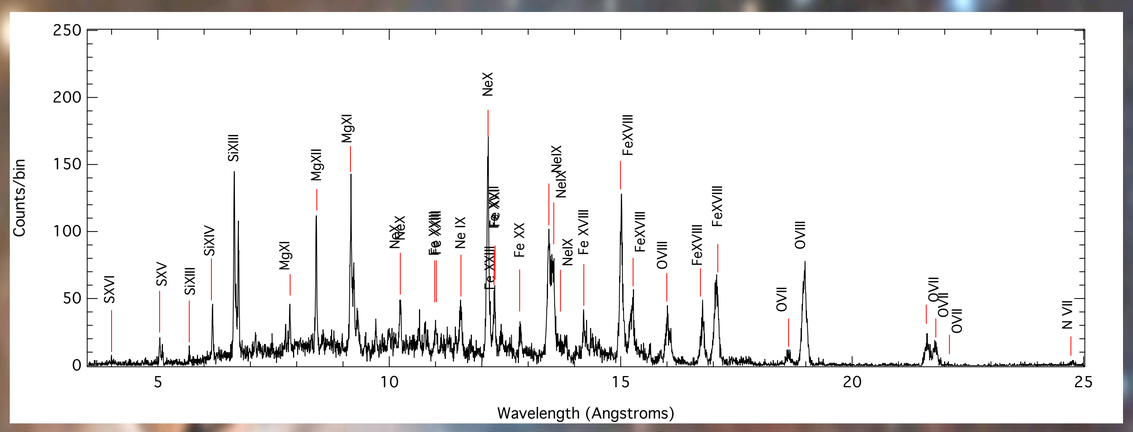
Chandra VLP Observing Log

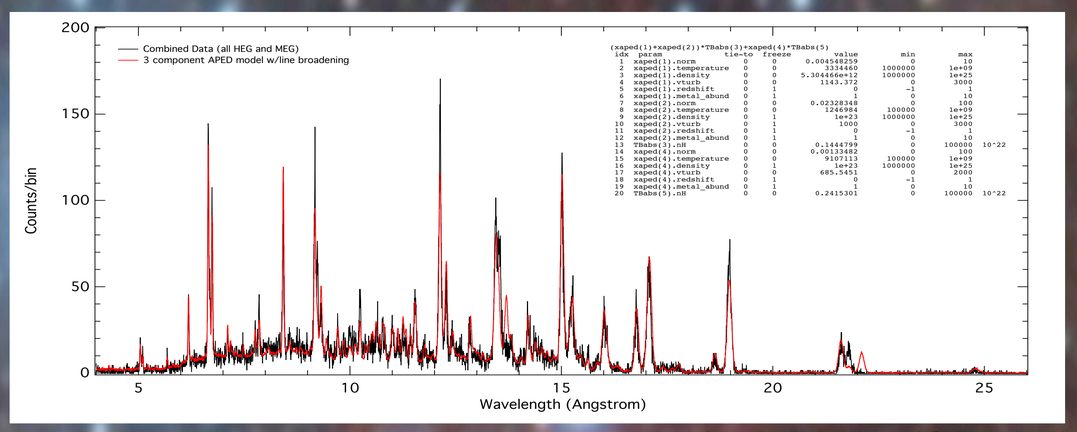
ObsID	14567	14568	14569	14570
Date Start	2012-12-19T16:54	2012-12-27T03:53	2012-12-22T06:06	2012-12-24T13:14
Phase Start	396.604	397.905	397.049	397.450
Date End	2012-12-21T01:48	2012-12-28T14:50	2012-12-23T16:12	2012-12-26T00:23
Phase End	396.844	398.159	397.297	397.705
Duration (Days)	1.34	1.46	1.42	1.46
Exposure (ksec)	115	122	119.3	122.5

δ Ori Parameters

Stellar Parameters		
	Star Aa1	Star Aa2
Sp. Type	O9.5II	B0.5 III
$R(R_\odot)$	17	7
$M(M_\odot)$	25	10
T_{eff} (K)	32900	24000
L_{bol} $(10^5 L_\odot)$	2.2	0.2
$\log g_{eff}$	3.38	3.76
$\dot{M}(M_\odot\ \mathrm{yr}^{-1})$	10^{-6}	10^{-7}
V_∞	2000	1500
System Parameters		
P (days)	5.732436	
e	0.09	
i	67°	
ω	148°	
$T_{periastron}(MJD)$	54002.205 ± 0.060	

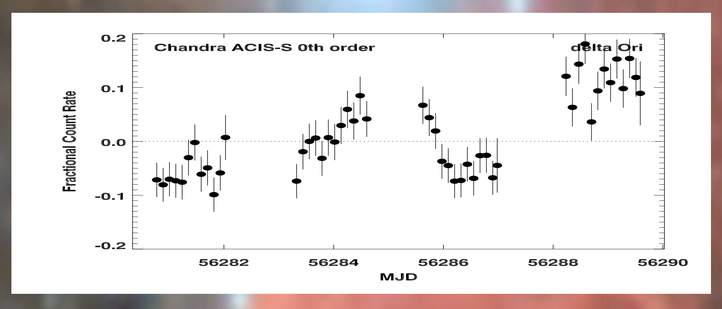
The Delta Ori HETGS spectrum:



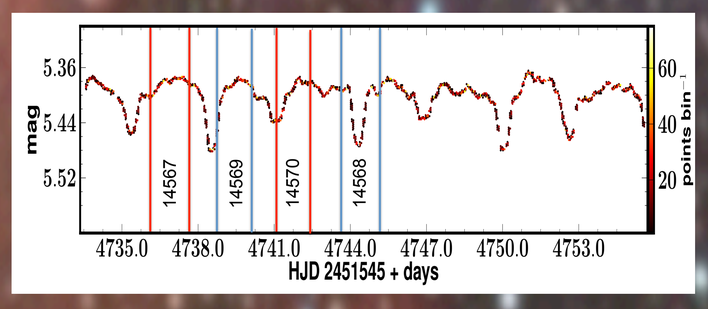


left: combined 478 ksec HETG spectrum of Delta Ori. right: simple 2 component fit to the combined spectrum, which recovers the line spectrum and continuum and which shows the suppression of the forbidden lines of OVII and Ne IX.

X-ray and Optical Variability



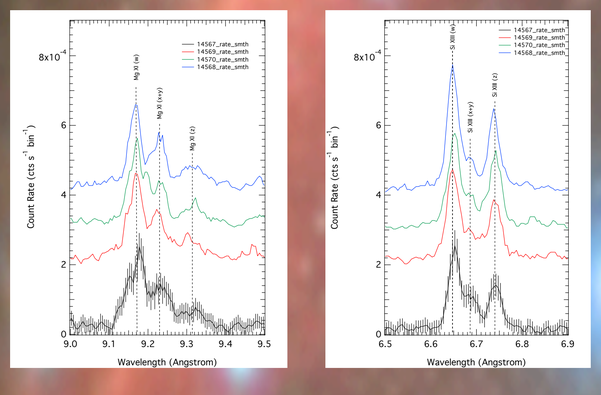
Chandra Zeroth-Order X-ray lightcurve (4-30 Angstroms)



MOST lightcurve (3500-7000 Angstroms, courtesy MOST team). The vertical lines show the timing of the Chandra observations.

- *Unusually large variations in the X-ray lightcurve*
- *Significant non-phase-locked photometric variations: pulsations?*

He-like Lines: Mg XI and Si XIII



Summary

In December 2012 Delta Ori was observed by Chandra using the HETGS for a total of 478 ksec spanning an entire orbital cycle. Simultaneous photometric data with MOST was obtained. These observations show **changes** in the optical and X-ray photometry and X-ray emission line spectrum which are not strictly phase-locked, along with phase-locked variabilty.

See Poster by Nichols et al. for a summary of the variability analysis.

H-like Lines: Ne X and O VIII